SCIENCE OF INTEGRATED WATERSHED MANAGEMENT: LINKING POLLUTANT CONTROL PRACTICES WITH WATER QUALITY

M. Morrison[1], C. Nietch[1], J. Schubauer-Berigan[1], M. Hantush[1], D. Lai[1], F.B. Daniel[2], M. Griffith[3]

[1]National Risk Management Research Lab, [2]National Exposure Research Lab, [3]National Center for Environmental Assessment

LTG 3 Poster 08

Science Questions

LTG 3, Science Question #3
How can classification schemes, modeling scenario analyses, landscape classification, and economic projections be applied to provide alternatives for meeting water quality goals efficiently at multiple scales? What are the economic benefits of watershed management?

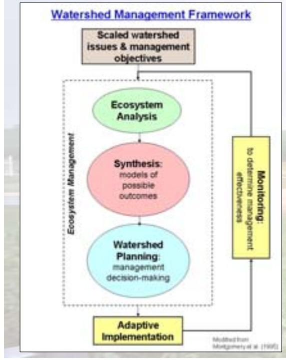
Research Questions
- How can best management practices (BMPs) be effectively selected, scaled and implemented at the watershed scale, and their integrated pollutant control performance be assessed?
- How can pollutant loading and fate be effectively monitored and modeled for use in the development and implementation of watershed management strategies?

How Research Addresses the Water Quality MYP Goals

ORD is working to integrate LTG 3 research efforts across disciplines and across ORD. A critical task in the integration effort is to understand the different disciplinary components, and how they fit together in developing a coherent watershed management framework. The majority of the research described in this poster is in the initial phases, and is only loosely coordinated. Ongoing efforts will improve collaboration, especially as individual projects near completion. Watershed research is integrative by nature, cuts across disciplines, and currently involves efforts by three ORD labs and centers.

Interactions with Customers

Watershed management research is highly collaborative and focused on interactions with customers. Results and products are disseminated through reports and face-to-face meetings at workshops and scientific conferences. Case studies typically involve local and State agencies, and often include EPA Regional offices and other Federal agencies.
- OWOW
- USEPA Regions
- Other Federal agencies, currently USGS and USDA



Research Objectives

The primary research objective is to develop tools and approaches that will improve water quality management decisions at the watershed scale.

The overarching goal of integrated watershed management research is to improve water quality outcomes through increased understanding and more effective implementation of pollutant control practices. Watershed management objectives need to be clear, and control practices must be scaled to both the spatial (i.e., headwaters catchment to large river basin) and temporal (i.e., days or months to decades) aspects of the impairment in order to be effective. The watershed management framework (at left) used to organize these efforts consists of four basic components:

1. **Ecosystem Analysis**
2. **Synthesis**
3. **Watershed Planning**
4. **Monitoring & Adaptive Implementation**

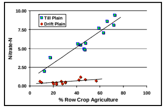
1. Ecosystem Analysis

Approach: Stream ecosystems can transition through a number of healthy and degraded states. Understanding ecosystem function and processes, and their relationship to ecosystem state, watershed land use and pollutant loading provides the foundation for watershed management.

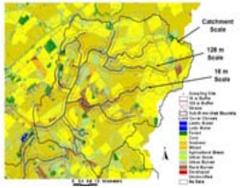
Methods:
- *Community metabolism* provides a measure of ecological function and processes that both respond to and alter nutrient and sediment cycling.
- *Suspended and bedded sediment* has a strong impact on ecological condition and nutrient cycling, particularly for phosphorus. Research in this area informs criteria development, using methods such as phosphorus binding, particle size distribution and loading rate analyses.
- *Ecoregion*-based approaches are important because the response of aquatic ecosystems to disturbance, their thresholds for pollutant loading, and their resilience may vary by Ecoregion.
- Research investigating *scaled land use* impacts and *scaled watershed size* is critical for determining the scale and placement of pollutant control practices for both watersheds and stream corridors.
- The *Experimental Stream Facility* uses model stream channels and controlled pollutant inputs to investigate fundamental aspects of ecosystem function.

Results: Ecosystem analysis research projects are relatively new, but have resulted in numerous presentations at scientific meetings. An internal report titled *The Use of Classified Hyperspectral Imagery to Assess Multi-scalar Land Cover Models for Predicting In-Stream Water Chemistry* was completed in July 2005.

Future Directions: Advanced monitoring technology will be combined with fundamental studies of nutrient cycling to provide more efficient, ecologically-based, approaches for evaluating pollutant control practices.



Nonpoint source nutrient loading and pollutant-induced ecosystem thresholds may vary systematically by Ecoregion (as above) and/or according to land use proximity to stream channels (see map, below).



How Research Contributes to Outcomes

OW, Regions, State and local governments will use the results of the research to more effectively plan and implement TMDLs and broader watershed management strategies.
- Ecosystem analysis research provides site-specific and regional data that is used to inform model and criteria development.
- Model applications synthesize ecosystem data and guide watershed planning efforts. Models are used extensively by our clients, and as such directly contribute to outcomes.
- Watershed planning research provides practical management frameworks that include economic assessments and often directly involve local and State agencies.
- Monitoring and analysis methods allow clients at all levels to better evaluate the results of management efforts.

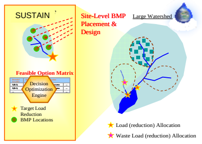
2. Synthesis

Approach: Decision support frameworks and model applications integrate water quality, hydrologic and ecological data from ecosystem analysis. Synthesis methods are used to predict pollutant loads and changes in ecosystem condition, and to optimize scale and watershed placement for pollutant control practices. These methods are also combined with economic analysis to compare management scenarios and optimize cost.

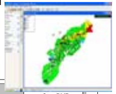
Methods:
- *SWMM* (Stormwater Management Model) is a dynamic rainfall-runoff model for single-event or continuous flow simulation. SWMM is used for nonpoint source water quality and routing simulation, and has been used extensively for modeling best management practices in urban watersheds.
- *SWAT* (Soil & Water Assessment Tool) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds.
- *SUSTAIN* (at right) is being developed to integrate BMP placement with economic analysis and optimization.

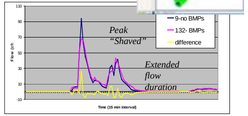
Results: Synthesis research is strongly collaborative and focused on short-term results. EPA publication 600/R-05/080 (July 2005) reports on the use of SWAT to identify sediment and nutrient sources and to evaluate scale-dependent BMP effectiveness in Black Creek, IN.

Future Directions: Continued calibration, practical application and field validation of models and decision support tools, as well as better integration with adaptive management, monitoring and results.



System for Urban Stormwater Treatment and Analysis INtegration (SUSTAIN) is a decision support tool for BMP placement and cost optimization.





Stormwater Management Model (SWMM) representation and output for course and fine headwater models.

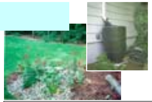
3. Watershed Planning

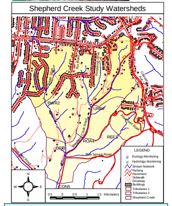
Approach: Based on ecosystem analysis and model simulations, but informed and constrained by social and economic analyses, watershed management decisions must be practical and capable of being implemented within a reasonable time frame. Watershed planning efforts must have concrete objectives and be scaled according to the magnitude of the impairment and its contributing source area.

Methods:
- *Low impact development* (LID) alternatives, including retrofits for existing residential areas, are an active part of watershed planning research.
- *Economic analysis*, including valuation techniques, benefit-cost analysis, incentive-based management and water quality trading approaches, is used to optimize the cost of watershed planning.
- *Water quality trading*, with an emphasis on wetlands, is the focus of a new collaborative effort between ORD and the Office of Water.
- *Total Maximum Daily Load analyses* (TMDLs) are an important tool for watershed planning, and many current research efforts involve impaired watersheds and/or support tools and approaches that will improve TMDL development.

Results: The majority of this research is in the beginning stages, but refer to LTG 3 Poster 9 for more information on the Cheat River Watershed project.

Future Directions: Efforts to integrate best management practice scale and placement options with innovative economic analyses will continue. The focus will be on partnerships and pilot projects to evaluate different watershed planning approaches.





Shepherd Creek Pilot Project: Economic incentives for decentralized stormwater runoff management
- *Voluntary* implementation & *dispersed* placement of *rain barrels* and *rain gardens*
- *Integrated monitoring & analysis*: ecology, hydrology & water quality

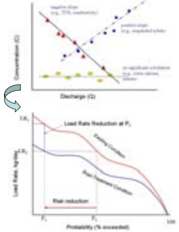
4. Monitoring & Adaptive Implementation

Approach: Monitoring of water quality at the watershed scale is expensive, time consuming and can easily generate too little or too much data. Methods are needed both to provide critical water quality and ecosystem condition data in a timely and cost-effective manner, and to analyze data for use in TMDLs and best management practice (BMP) effectiveness assessments. Adaptive implementation means that watershed planning must be responsive to monitoring data, but the analyses must be robust and the uncertainty of data and conclusions clearly quantified.

Methods:
- *Duration curve methods* are based on the regression relationship between discharge and pollutant concentration, and on the ranking of annual discharges into a probability distribution.
- *New technologies* are evaluated for usefulness in water quality monitoring programs, often in conjunction with ecosystem analysis. Parameters that are easily measured in-situ can provide useful surrogates for critical pollutants as long as the relationship is well characterized.
- *Regression techniques* are used to evaluate monitoring data, to look for changes in condition, to compare different sites and to establish relationships between land use, ecological condition and water quality. A wide range of statistical methods exist and continue to be evaluated.

Results: State and Federal agencies can and are using duration curves in the development of TMDL analyses (see, for example, the Kansas Dept. of Health and Environment at http://www.kdheks.gov/tmdl/Data.htm)

Future Directions: Continued focus on numerical methods to quantify the effects of pollutant control practices on water quality.



The duration curve approach is useful for BMPs and TMDL analyses.